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Termination of Safeguards on ULWBR Material

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Abstract:

The Department of Energy (DOE), Office of Environmental Management, has approved the disposition of 31 metric tons of Unirradiated Light Water Breeder Reactor (ULWBR) material in canisters stored within dry wells of the Underground Fuel Storage Facility at the Idaho Nuclear Technology and Engineering Center (INTEC). This unirradiated material consists primarily of ceramic pellets of thorium oxide in stainless steel cladding, but it also contains 300 kilograms of uranium that is 98 wt% U-233. The ULWBR material was not processed at the INTEC because it was incompatible with prior chemical separation schemes. Other economical recovery options were not identified, and expressions of interest for consolidating the material with existing projects at other DOE sites were not received. The U-233 might be used for producing the medical isotope Actinium-225, but the proof-of-principle demonstration and follow-on pilot program were not developed to the point of requiring production quantities of U-233. Consequently, the selected disposition of the ULWBR material was burial as Low-Level Waste at the Nevada Test Site (NTS), which required terminating safeguards controls for the contained Category II quantity of Attractiveness Level D special nuclear material (SNM). The requested termination followed the twelve point evaluation criteria of the Historical Defense Program Discard Guidance and included a security vulnerability analysis for evaluating the risks of theft, diversion, and radiological sabotage associated with the material. Continuity of knowledge in the book inventory was assured by documenting that the original shipper's measurements reflected the quantities of materials received and that the ULWBR materials had remained under adequate physical protection and had been subject to periodic physical inventories. The method selected for confirming the book values as the basis for terminating safeguards was the nondestructive assay used during physical inventories. Shipping arrangements included refurbishing a licensed Department of Transportation Type B cask to be reused over the duration of the disposal process. A corresponding batching plan and shipping schedule were developed to accommodate multiple commercial shipments of Category III quantities of SNM in the selected cask, such that all canisters would be received at NTS prior to the expiration of the nonrenewable cask license.

Introduction:

The Department of Energy (DOE) Office of Environmental Management (EM)—in consultation with the Office of Security—approved the disposition of 31 metric tons of Unirradiated Light Water Breeder Reactor (ULWBR) material within 40 canisters stored in 20 dry wells of the Underground Fuel Storage Facility (UGFSF) at the Idaho Nuclear Technology and Engineering Center (INTEC). The INTEC, formerly the Idaho Chemical Processing Plant, is an EM managed facility located at the Idaho National Laboratory (INL) and is operated for DOE by CH2M-WG Idaho, LLC (CWI). However, the Safeguards unit of Battelle Energy Alliance, LLC (BEA) provides the nuclear materials control and accounting functions for the INTEC, including the oversight of safeguards terminations.

The selected mode of disposition was long-term storage of the ULWBR material as Low-Level Waste (LLW) by burying the material in its existing canisters at the Nevada Test Site (NTS). This disposal required terminating safeguards controls for a collective Category II quantity of

Attractiveness Level D special nuclear material (SNM) in multiple transfers of Category III quantities. This paper describes the process followed by CWI and BEA for terminating safeguards controls for the ULWBR material. Although the termination concentrated on satisfying the Safeguards and Security requirements of DOE M 470.4-6 Chg 1, *Nuclear Material Control and Accountability*, the twelve point evaluation criteria of the *Historical Defense Program Discard Guidance* were also considered. The requested termination also considered the potential theft or diversion of the material and the risks of radiological sabotage.

Material Description

The ULWBR material resulted from the preliminary development and testing of the Shippingport Light Water Breeder Reactor, which was a water-cooled, breeder reactor used for the production of the fissile uranium isotope (U-233) from the fertile thorium isotope (Th-232). Upon completion of reactor operation, the shipper, Bettis Atomic Power Laboratory, packaged the ULWBR material in 40 storage canisters, applied an E-cup, Tamper-Indicating Device (TID) to each canister lid, and shipped the canisters to the INTEC in a Super Tiger Cask (Department of Transportation Type B cask). Upon receipt, the canisters were placed vertically, at two canisters per well, in 20 of the UGFSF dry wells. The shipper's TIDs were not removed.[1] The initial receipts were placed in the UGFSF between December of 1984 and December of 1985, with a later receipt arriving in June of 1987. When shipped to the INTEC, the ULWBR material had no anticipated use in its existing form, and it was incompatible with the existing INTEC chemical separation schemes. Thus, the material did not undergo reprocessing but remained undisturbed in safe and secure storage for over 20 years.

The 40 canisters contain approximately 15,000 unirradiated blanket rods and miscellaneous scrap consisting primarily of thorium (a source nuclear material) but with a significant quantity of uranium, nearly all of which is U-233 (an SNM). The rods are constructed of oxide pellets within zircaloy or stainless steel cladding. The vast majority of the pellets are sintered thorium dioxide (ThO_2), but a small portion consists of a binary mixture of ThO_2 and uranium dioxide (UO_2). Within all 40 canisters, the material has an overall weight of 31.4 metric tons, of which the nuclear materials consist of 13.8 metric tons of thorium and 306.6 kilograms of uranium. The Th-232 constitutes 97.8 weight percent (wt %) of the contained nuclear materials, while the remaining 2.2 wt% is uranium. At 98.1 wt% of the total uranium, the U-233 is the only significant fissile uranium isotope; the remaining uranium is about 1.3 wt% U-234 and 0.4 wt % U-238, with only trace amounts of the other uranium isotopes. Overall, the U-233 makes up slightly less than 1.9 wt% of the oxide pellets. Although the material is unirradiated, the radioactive decay resulting from the Th-232 Radioactive Decay Series, created radiological fields ranging from 500 mR/hr to 1 R/hr at canister contact.

From a safeguards perspective, the material within the 40 canisters constituted a Category II quantity of Attractiveness Level D SNM; but from a waste management perspective, it also qualified as LLW. Although radioactive, the ULWBR material was not high-level radioactive waste, spent nuclear fuel (SNF), transuranic waste, mill tailings, or byproduct material. Furthermore, the ULWBR material was not a mixed waste because it was not a listed hazardous waste nor was it characteristically hazardous under the regulations of the Resource Conservation and Recovery Act.

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[1] In addition to the 40 canisters, a seed module was shipped in a separate cask and placed in an individual UGFSF dry well. However, the termination of safeguards for the seed module, including the location of an acceptable disposal site, is yet to be pursued.).

Selected Disposition

Prior attempts to identify potential uses for the ULWBR material were unsuccessful. Expressions of interest in the material in its existing form for use at other DOE sites were not received, and a near-term, economically-viable recovery of the contained U-233 appeared to be infeasible.

In an October 2002 memorandum, the EM Assistant Secretary identified four options for the disposal and consolidation of excess accountable quantities of EM-owned nuclear materials. Option 3 allowed for transferring custody of materials having an approved mission need to the appropriate Lead Program Secretarial Office (LPSO). In response to this memorandum, the DOE-Idaho Operations manager issued a December 2002 memorandum for soliciting expressions of interest in excess materials on the INTEC inventory, including the ULWBR material. The memorandum was issued to the National Nuclear Security Administration (NA-1), the Office of Nuclear Energy, Science & Technology (NE-1), and the Office of Science (SC-1); but none of these agencies responded with an interest in the ULWBR material.

In a separate negotiation, BEA expressed an interest in stockpiled U-233 by requesting that CWI support a Cooperative Research and Development Agreement for producing the medical isotope, Actinium-225. However, the proof-of-principle demonstration and follow-on pilot program had not developed to the point of requiring production quantities of U-233, and a period from five to seven years was projected before the need would arise. As an alternative to disposing of the ULWBR material as waste, CWI offered to transfer ownership of the material to BEA (under the NE LPSO) in order to retain the contained U-233 for future use. CWI informed BEA of the costs for continued storage in the UGFSF and noted that the transfer had to occur prior to September 30, 2009, the deadline in which CWI was contractually bound to divest itself of all EM-owned SNM. The custody transfer was also contingent upon the stipulation that any subsequent disposition of the ULWBR material, if required, would be the responsibility of the NE LPSO. However, the proffered transfer did not transpire, leaving CWI no choice but to pursue disposition of the ULWBR material as waste.

The NTS is authorized to operate permanent disposal sites that meet the LLW requirements of DOE O 435.1, *Radioactive Waste Management*. NTS Disposal Area 5 is a 732-acre waste management area, of which 160 acres is reserved for the storage of radioactive waste. To dispose of the ULWBR in Disposal Area 5, the waste profile was completed; and after demonstrating that the NTS waste acceptance criteria were satisfied, NTS agreed to accept the 40 canisters for burial as LLW. The disposal of the ULWBR material was to be permanent; there was no intention to regain access to the material or to reverse its declaration as waste.

Historical Defense Program Discard Guidance

In an April 1994 memorandum, the Office of Nuclear Weapons Management promulgated twelve criteria for the disposition of plutonium bearing materials for other than economic factors. Although separate from the termination requirements of DOE M 470.4-6, these criteria have since been incorporated as a form of quasi or subsidiary requirements, and the application has expanded to include all nuclear materials. Altogether, these criteria consider: worker safety, minimizing environmental impact, regulatory concerns, waste minimization, disposal technical criteria, technical risk, stakeholder interest, risk assessment, implementation time/feasibility, proliferation potential, cost, and interim storage. All twelve criteria were evaluated in terminating safeguards for the ULWBR material, but only the proliferation potential is discussed here, because it is most inline with the Safeguards and Security considerations.

For the ULWBR material, the potential for proliferation was tantamount to the comparative ease of extracting the dilute U-233 isotope from its thorium matrix. Under the assumption that the blanket rods were successfully removed from the UGFSF storage, consideration was given to the ease of mechanically handling the rods, dissolving and conditioning the material, separating the uranium from the solute, and converting the separated U-233 to SNM metal. As noted, the ULWBR material was incompatible with the existing chemical separation schemes at the INTEC. In a November 2001 report issued by the DOE National Spent Nuclear Fuel Program, titled *Separability of Department of Energy Spent Nuclear Fuel Relative to Commercial Spent Nuclear Fuel*, Thorium and Uranium Oxide Ceramic Fuels were generally assessed to be harder to process than commercial fuels. Thus, a sophisticated processing operation would be required for extracting weapons-grade U-233 from the ULWBR material, which thereby reduced its attractiveness for proliferation potential.

Continuity of Knowledge

Transfers of SNM undergoing safeguards termination must be based on measured values, but the ULWBR material was not independently measured upon its arrival at the INTEC. The convention at the time was to provisionally accept the shipper's measurements, as stated on the accompanying external transfer documents (DOE/NRC Form 741, *Nuclear Material Transaction Report*). The provisional values were recorded on the INTEC book inventory, but they were subject to adjustment by quantitative measurements when the material was eventually processed. As noted, the ULWBR material did not undergo reprocessing. Thus, the recorded shipper's measurements were never verified by destructive analyses associated with the separations process. Neither were the shipper's values verified by nondestructive assay (NDA), due to the intractability of handling and opening the massive canisters for removing the contents and the lack of an NDA facility. Nonetheless, BEA Safeguards affirms that "continuity of knowledge" for the recorded values was maintained from the time that the ULWBR material was received until it was shipped offsite. Continuity of knowledge implies an assurance that the SNM values, as recorded on the book inventory, accurately reflect the quantities of materials that are physically present, because the values were determined using approved measurement methods, and the materials had remained under constant physical protection (access controls, containment and surveillance measures) and were subject to periodic physical inventories.

Although the ULWBR material was not quantitatively re-measured in conjunction with termination of safeguards, the validity of the shipper's values was assured by BEA Safeguards personnel through record searches of the shipper's supporting data. Thus, the shipper's original measurements that were recorded on the book inventory formed the basis for the material transfer. These values were confirmed using the same qualitative NDA for confirming the presence of the material during semiannual physical inventories.

Ever since the ULWBR canisters were placed in the dry wells of the UGFSF, safeguards and security measures per DOE requirements were in place to maintain control of the contained SNM. The UGFSF is enclosed within a protected area (PA) within the INTEC property protection area (PPA). As such, the area is controlled for access, is equipped for intrusion detection, and is subject to random patrols by the protective force. The effort required to surreptitiously hoist a canister from its well and to haul the canister from the PA boundary of the UGFSF would have been an arduous task even with the necessary lifting equipment, and the time required for completing the task would have far exceeded the response time of the guard force.

In addition to the external protection afforded by a PA within a PPA, the bulk mass of the loaded canisters and the storage configuration in the UGFSF storage wells provided inherent physical security for the contained ULWBR material. The canisters are constructed of stainless steel pipe that is approximately 125" (~10½ feet) in length, with an 8.62" outer-diameter (7.62" inner-diameter) and a 0.5" wall thickness. Each canister has a 0.25" thick, bottom cover that is welded in place and a top cover or plug (a 2" thick by 8.62" diameter plate) that is machined to fit 1.75" into the canister top. The canister cover is connected to the canister by four self-locking screws, which when in place, are flush with—and at a 90-degree angle to—the canister wall. In this configuration, the canister cover could not be removed and hands-on access to the ULWBR material was not possible, without removing the canister from its dry well. The hoisting was accomplished by means of a threaded hole in the canister lid, for attaching eyebolts or lifting rods to the canister top. Due to the massive weight of a filled canister (between 1400 to 2000 pounds), a mobile hydraulic crane having a lifting capacity of 2000 pounds and about 15 feet of ground clearance, together with the necessary lifting paraphernalia, was required for hoisting a canister.

Although the massive weight of each canister provided built-in protection for the contained SNM, it also complicated the performance of semiannual physical inventories, due to the intractability of retrieving the individual items for visual examination and NDA. And although the radiation levels were not life threatening, the repeated retrieval and handling of the individual items could have resulted in excessive dose rates. For these reasons, a deviation from traditional inventory methods was accepted by DOE Headquarters for physically inventorying the material. The approved compensatory measures were as follows. For each randomly selected dry well, the access plug to the well cover was removed, and the presence of the top canister was visually verified, including the identity of the shipper's TID, if visible. Gamma-ray spectroscopy was then used for detecting the dominant Th-232 gamma-ray signature, having a characteristic energy level of 2614 KeV. (The sought after, but comparatively weak, U-233 peak was masked by the thorium Compton background.) Although an above-background Th-232 peak did not confirm the presence of the U-233 (the SNM), it did confirm the presence of the thorium/uranium oxide matrix. Thus, considering the immobility of the ULWBR canisters, a visual inspection of the shipper's TID that revealed no anomalies, together with an identifiable Th-232 signature, provided assurance that none of the SNM had been diverted.

Loading/Shipping Arrangements

The approved disposition was by burial of the ULWBR material in the existing 40 canisters; thus, the material was not repackaged as part of safeguards termination. Furthermore, the same type of cask (Super Tiger) that was used for initially shipping the ULWBR material to the INTEC was used for subsequently transferring the 40 canisters to NTS. However, only one certified Super Tiger Cask was available; and its certificate of compliance was to expire at the end of fiscal year 2008. The Super Tiger Cask fits on a flatbed trailer and can house up to four ULWBR canisters. Consequently, an aggressive schedule was developed for batching the 40 canisters in sequential shipments, of at most four canisters each, such that all canisters were transported to NTS prior to the expiration of the cask's certificate.

The canisters were ultimately batched, at three or less per shipment, such that the contained U-233 was less than 16 kilograms, thereby ensuring that the cask never contained more than a Category III quantity of Attractiveness Level D SNM. The limiting of each shipment to a Category III quantity and the reuse of a single cask satisfied two security concerns. First, the collective Category II quantity of ULWBR material was transported in multiple shipments via a commercial carrier, which eliminated the need for coordinating the transfers through the Office of

Secure Transportation. Second, the sequential shipments of Category III quantities eliminated the potential rollup of a Category II quantity being transferred at any one time, which otherwise might have occurred with simultaneous commercial shipments of Category III quantities.

The projected shipping dates were spaced such that each batch of ULWBR material was shipped and the Super Tiger Cask returned prior to the next scheduled shipment. The requesting and receiving of approval to ship was likewise negotiated between INTEC and NTS, in order for the authorization for the succeeding shipment to be obtained prior to the ensuing shipment date. Anticipated concerns with the aggressive shipping schedule included inclement weather that could delay canister loading and discrepant conditions, such as broken TIDs, that would prompt safeguards investigations and the appropriate notifications and resolutions.

Physical preparations included the fabrication of lifting tools and loading/unloading mechanisms and platforms that were used at both INTEC and NTS for hoisting the canisters and transferring them to/from the Super Tiger Cask. The associated training for personnel at both facilities was required, and all processes were included in applicable operating procedures and safety documents. The Super Tiger Cask also underwent minor refurbishment, which included reinforcing welds and replacing weathered or worn out components, including the foam surrounding the cask insert, the door gaskets, and various nuts and bolts.

The loading of each shipment involved hoisting the top of a selected canister to ground level for verifying that the canister identity and applied TID matched safeguards documentation. After which, the canister was hoisted about halfway from the well for confirming the U-233 content by observing the presence of the dominant Th-232 gamma-ray peak at 2614 KeV. (This was the same NDA method used for confirming the presence of the U-233 during semiannual physical inventories.) The canister was then removed from its dry well and transferred to one of four storage ports in the Super Tiger Cask located on the flatbed trailer. After all canisters of each batch were loaded, the cask was closed, a safeguards TID was applied, and the loaded cask was staged within the PA of the UGFSF, generally until the following workday. While awaiting shipment to NTS, the shipper (CWI) retained ownership of the contained Category III quantity and provided the necessary physical protection per the UGFSF security plan. When the cask was released for shipment, a transfer check was conducted, including an examination of the previously-applied TID.

The requirements for safeguarding the Category III quantity within each shipment were terminated when the loaded Super Tiger cask crossed the INTEC PPA boundary. The contained ULWBR material, although a Category III quantity of SNM, was then declared as waste (non-accountable nuclear material), and custody of the material was transferred to the NTS waste management organization. Each shipment constituted an external transfer between facilities having different reporting identification symbols, and the quantity of shipped material was documented on DOE/NRC Form 741 and subsequently removed from the INTEC book inventory.

Burial at NTS

Disposal Area 5 at NTS is within a PPA having a fenced boundary, access controls, and protective force surveillance. Once within the area boundary, the Super Tiger Cask underwent a standard waste receipt inspection; and within the day of arrival, each ULWBR canister was offloaded from the Super Tiger Cask. When placed within a disposal cell, each canister was placed horizontally in a separate trench, with applicable distance between trenches. Thus, the

potential for rollup to greater than a Category III quantity was eliminated because the ULWBR material, which was declared non-accountable nuclear material, was sufficiently spaced that it was not collocated with other accountable nuclear material. The canisters were then covered under a sufficient amount of dirt to seriously hinder any attempts at theft or diversion. The empty Super Tiger Cask was then returned by the commercial carrier for loading the next set of canisters. This cycle for terminating safeguards controls on the Category III quantity of SNM within each batch of canisters continued until all 40 ULWBR canisters were removed from the INTEC and disposed by burial at NTS.